**NASA DEVELOP National Program**

NASA Ames Research Center

**Summer 2016**

**Short Title: San Francisco Bay Area Health & Air Quality**

**Subtitle:** Using Satellite, Aircraft, and Ground-Based Observations to Monitor Methane and Improve a Greenhouse Gas Inventory Network for the San Francisco Bay Area

**VPS Title:** The Steaks are High! Methane on the Rise

**Project Team & Partners**

**Project Team:**

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**Advisors & Mentors:**

Dr. Abhinav Guha (Bay Area Air Quality Management District)

Dr. Laura Iraci (Ames Research Center)

Dr. Josette Marrero (NASA Postdoctoral Program)

Dr. Warren Gore (Ames Research Center)

Dr. Emma Yates (Bay Area Environmental Research Institute)

Dr. Juan Torres-Pérez (Bay Area Environmental Research Institute)

**Partner Organizations:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| Bay Area Air Quality Management District (BAAQMD) | Dr. Abhinav Guha, Senior Air Quality Engineer;  Dr. Phil Martien, Air Quality Engineering Manager | End-User | Yes\* |
| NASA Alpha Jet Atmospheric eXperiment (AJAX) | Dr. Laura Iraci, Atmospheric Chemist, PI; Dr. Emma Yates, Atmospheric Chemist; Dr. Josette Marrero, Atmospheric Chemist; Dr. Warren Gore, Chief ARC Atmospheric Branch | Collaborator | No |

**Project Details**

**Applied Sciences National Applications Addressed:** Health & Air Quality

**Study Area:** San Francisco Bay Area, CA

**Study Period:** June 2011 to December 2015

**Earth Observations & Parameters:**

Landsat 5 TM, 7 ETM+, 8 OLI – Land cover applications

USGS High Resolution Orthoimagery – black-and-white, natural color, and color infrared aerial photographs

RapidEye Constellation – natural color orthoimagery

PlanetScope Constellation – natural color orthoimagery

**Ancillary Datasets Utilized:**

* Bay Area Air Quality Management District *in situ* Greenhouse Gas Measurements - CH4 measurements
* Bay Area Air Quality Management District shapefiles - locations of CH4 sources
* NASA Alpha Jet Atmospheric eXperiment (AJAX) – methane (CH4), carbon dioxide (CO2), water vapor, altitude, pressure, temperature, and 3-D wind speed
* NOAA Global Monitoring Division Baseline Air Quality - a priori CH4 measurements
* NOAA Quality Controlled Local Climatological Data (QCLCD) - hourly meteorological observations

**Models Utilized:**

* TerrSet Earth Trends Modeler (ETM)

**Software Utilized:**

* ArcGIS – Map CH4 concentrations
* ENVI – Map CH4 concentrations, Classification of Landsat and MODIS images (also ArcGIS)
* MatLab- File conversion and analysis
* R studio – Statistical analyses
* Anaconda / Jupyter Notebook - Statistical analyses
* Google Earth Pro - Data visualization
* TerrSet - Create time series to assess seasonal and anthropogenic fluctuations in CH4 and identify localized sources of CH4.

**Project Overview**

**80-100 Word Objectives Overview:**

The spatial and temporal variation in CH4 concentrations over the San Francisco Bay Area can be monitored using ground-based *in situ* and aircraft-based measurements. These measurements are used to identify CH4 hotspots and trace the origins of CH4 plumes to possible local point sources. Land classification with remote sensing Earth observations are used to locate other possible sources for further monitoring by the BAAQMD Mobile Greenhouse Gas Measurement Network.

**Abstract:**

CH4 is the second most important anthropogenic greenhouse gas in terms of radiative forcing, with methane emissions coming from a variety of human-induced sources in populated areas, such as livestock, landfill, and wastewater. The Bay Area Air Quality Management District (BAAQMD) uses traditional bottom-up methodologies to produce source-specific emissions estimates for their regional greenhouse gas inventory; however, recent literature demonstrates that bottom-up methodologies are underestimating CH4 emissions by up to 50% in many regions of California, including the San Francisco Bay Area. This discrepancy is investigated in this project by comparing ground-based *in situ* greenhouse gas measurements with sub-Planetary Boundary Layer aircraft measurements from the NASA Alpha Jet Atmospheric eXperiment (AJAX). Understanding the spatial and temporal variations in CH4 can help identify hotspots and trace the sources of high-CH4 plumes. Additionally, this project utilized land classification to identify the associated sources, and search for other similar sources that are not included in the current BAAQMD emissions inventory. Integrating these findings into their traditional bottom-up methodologies have offered a more accurate approach to compiling this inventory. Furthermore, the identification of possible high-emission point sources may suggest areas of future *in situ* measurement for the agency’s Mobile Greenhouse Gas Measurement Network, or remotely sensed total column measurements by targeted greenhouse gas satellites such as Greenhouse Gases Observing Satellite (GOSAT).

**Keywords:**

Air Quality, Emissions, Planetary Boundary Layer (PBL), Remote Sensing

**Community Concerns:**

* Methane is the second most important anthropogenic greenhouse gas in terms of radiative forcing, with a global warming potential of 34 on a 100-year time scale (IPCC 2013).
* Increases in CH4 emissions influence the climate in two ways: 1) by increasing the absorbing capacity of infrared radiation; and 2) indirectly, by contributing to higher concentrations of tropospheric ozone (O3), an air pollutant associated with diminished air quality and adverse health effects.
* The San Francisco Bay Area, a coastal and low-elevation region, has a direct community concern in methane’s global warming potential, as sea level is predicted to rise 6 to 16 inches by 2050 with current warming models.

**Current Management Practices & Policies**:

Currently, BAAQMD relies primarily on bottom-up greenhouse gas (GHG) inventories to estimate emissions. In addition, as part of the Regional Climate Protection Strategy, BAAQMD has recently implemented the Bay Area Greenhouse Gas Network. This network consists of: 1) four long-term, ground-based GHG monitoring stations, consistent with protocols of international atmospheric monitoring networks (two began collecting data in October 2015, two in May 2016), and 2) a mobile GHG measurement platform (instrumented Air Monitoring Van, AMV) equipped with analyzers capable of measuring isotopic methane (13C – CH4), CH4, CO2, and nitrous oxide (N2O) in ambient air at fast temporal rates. However, due to the limited spatial and temporal resolution of these *in situ* measurements, BAAQMD’s GHG Network is unable to quantify local and point-source methane emissions. Additional understanding of seasonal and annual trends in Bay Area CH4 is necessary to contextualize the recent and ongoing measurements in keeping with the Regional Climate Protection Strategy.

**Decision Support Tools & Benefits:**

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| --- | --- | --- | --- |
| **End-Product** | **Earth Observations Used** | **Benefit & Impact** | **Software**  **Release** |
| Statistical comparisons of aircraft, ground-based, and satellite CH4 measurements | CH4 retrievals from NASA AJAX. BAAQMD on-site CH4 measurements | These comparisons will help the end-user understand the potential of satellite observations for CH4 emissions measurement, and advance understanding of discrepancies in current emissions estimates. | N/A |
| Spatial and Temporal Analyses Maps of CH4 Distribution for San Francisco Bay Area | CH4 retrievals from NASA AJAX, NOAA Earth System Research Laboratory Global Monitoring Division Baseline Observations | These maps will provide spatially-resolved distributions of CH4 across the nine San Francisco Bay Area counties. | N/A |
| Hotspot Map | CH4 retrievals from NASA AJAX, NOAA Earth System Research Laboratory Global Monitoring Division Baseline Observations, USGS High Resolution Orthoimagery - black-and-white, natural color, and color infrared aerial photographs  Planet Labs - RapidEye natural color (RGB) imagery and PlanetScope orthorectified visual imagery | The Hotspot Map will identify possible sources of CH4 not already accounted for in the current BAAQMD emissions inventory, and identify other similar landforms for future *in situ* monitoring by the BAAQMD Mobile Greenhouse Gas Measurement Network or remotely sensed total column measurements by targeted greenhouse gas satellites such as Greenhouse Gases Observing Satellite (GOSAT). | N/A |

**Project VPS/Booklet Imagery**



**Caption:** AJAX flight path over the San Francisco Bay Area with points indicating methane concentrations from low (green) to very high (red). Image Credit: San Francisco Bay Area Health and Air Quality team.

**Image:** 2016Sum\_ARC\_SanFranciscoBayAreaHealthAQ\_FinalImagery